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MARS AT THE 1956 OPPOSITION

By Peter M. Millman

Ever since August 1924, when with teenage enthusiasm I persuaded my father to help me haul a three-inch telescope to the top of a Japanese mountain (Millman, 1926), the planet Mars has had a fascination for me. I am no expert on planetary observation and, except for a series of drawings of Mars made in 1930–31 with the Harvard 12-inch polar telescope, I have made only casual observations of the surfaces of the planets.

At the recent favourable opposition of Mars it seemed of interest to find out just how much could be seen with an instrument of moderate power under the average atmospheric conditions encountered at Ottawa. To maintain maximum objectivity in the visual recording no detailed maps of Mars were referred to all year and the central longitudes on the disk were not looked up during the progress of the observations. Although it was impossible not to recognize at sight two or three of the outstanding surface markings of Mars, no attempt was made to identify the detail seen until the accompanying map (figure 1) had been plotted in its final form.

The observations were made with the 15-inch refractor of the Dominion Observatory, Ottawa, focal length 225 inches. A highly corrected eyepiece giving a power of 155 × was used almost exclusively. Higher powers, when tried out, gave inferior results. Various colour filters were also used occasionally but were not satisfactory. Sixty-eight drawings were made on eleven nights, as listed in the following table.

No micrometer measures were made, detail being plotted by eye on circles of 2-inch diameter. Each drawing took between 5 and 10 minutes to complete and drawings were made on the average one every half-hour. The map in figure 1 has been compiled from all the drawings,

	Date	*Drawings*	*Seeing*
I	Aug. 17/18	8	good
II	24/25	10	good
III	Sep. 2/3	7	average
IV	5/6	2	poor
V	7/8	10	good
VI	14/15	3	very poor
VII	20/21	6	average
VIII	21/22	8	poor
IX	28/29	4	poor
X	Oct. 5/6	6	average
XI	19/20	4	poor
		68	

using a globe and a graphical projection method to determine the Martian co-ordinates. In general, mean positions for all markings visible were determined for each night of observation and the final map was plotted from a weighted mean of these individual night averages. The surface features were then identified by reference to the detailed maps of Antoniadi (1930), and the ALPO Map of Mars for the 1954 opposition (Avigliano, 1956), and are indicated in figure 2. The central Martian latitude was very near 20° S. for all drawings, therefore detail is most accurate for the latitudes within 30° of this. The central meridians for the 68 drawings are indicated by small dots in figure 2, the Roman numerals referring to the observing nights.

Although eye estimates of the relative darkness of various markings are greatly influenced by a number of factors an attempt was made to use a qualitative darkness scale based on 0 for the polar cap and 10 for the darkest markings. The Arabic numerals appearing in figure 2 are the darkness scale averages for all the observations. The Syrtis Major would probably have had a higher figure had it appeared nearer the centre of the disk.

The average apparent diameter of the disk of Mars was 2″.35 for these observations. The theoretical resolving power of a 15-inch telescope is 0″.34 so the theoretical limit of resolution on Mars should have been 1°.5 in Martin co-ordinates at the centre of the disk. In general the finest detail seen was two or three times this value which, in consideration of the seeing, is about right. At rare intervals a mass of fine detail in the dark areas would appear instantaneously, but this disappeared so quickly it was impossible to plot it.

The apparent positions of the markings may have been influenced by

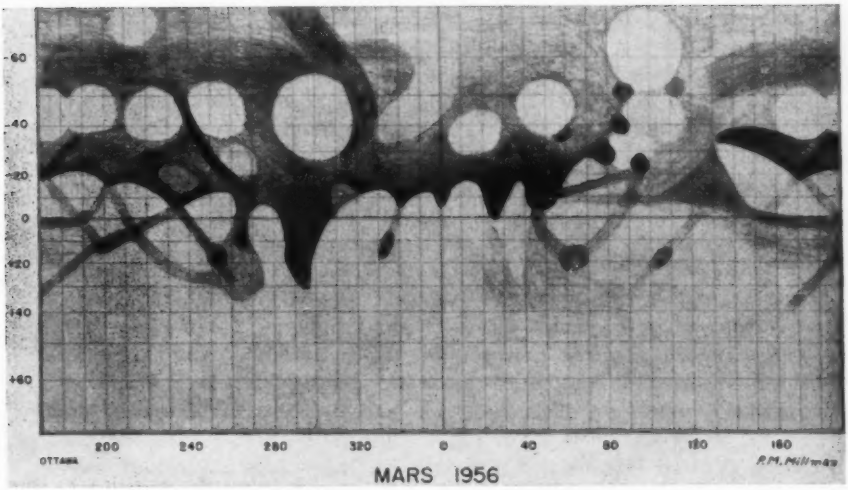

FIG. 1—Map of Mars from drawings made with the 15-inch refractor at the Dominion Observatory.

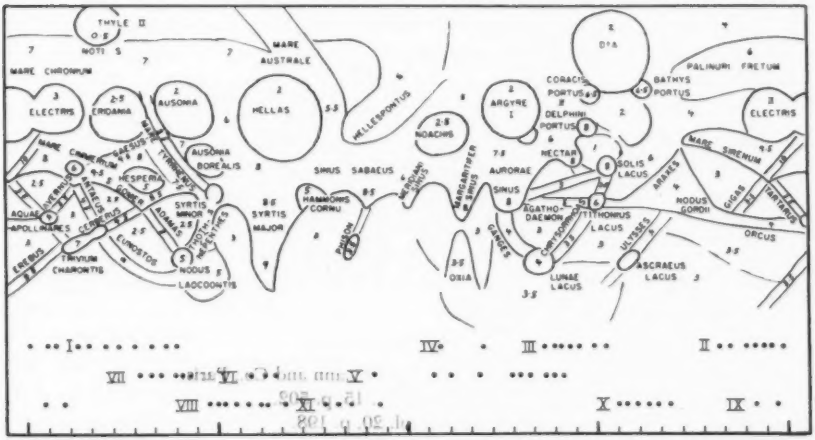

FIG. 2—Identification of detail shown on the map. Dots indicate the central meridian for the 68 drawings.

clouds, and no attempt was made to correct for this as it would have been necessary to refer to maps of Mars to identify cloud positions. The south polar cap was prominent during August, then disappeared during the first week in September. By the middle of September it was visible again and by the first week of October it was more prominent than ever. This disappearance of the pole cap was apparently caused by obscuring clouds.

Some 20 canal-like features were observed, the two strongest being one I have tentatively identified as Adamas, and a canal running from Aurorae Sinus to Solis Lacus. This latter does not seem to agree with previously observed detail and for some reason it may have been plotted too far south on this map. To me, both in 1930 and 1956, the canals have appeared like fairly dusky bands. I have no doubt about their objectivity but it seems quite possible that, with higher revolving power and better seeing, they might reveal irregularities and discontinuities.

A refractor is not a good instrument for the study of colours, but colour values on Mars were looked for carefully. No evidence of any blue or green was seen in the dark markings, just a general neutral shade of gray with possibly a touch of brown. This agrees with Kuiper's report at the 96th Meeting of the American Astronomical Society on observations at the McDonald Observatory in 1956.

No high accuracy or great significance is claimed for the observations reported here. They are placed on record merely as an example of a completely independent attempt by a relatively inexperienced planetary observer to record objectively the most prominent features visible on Mars in 1956.

In conclusion I should like to express my sincere thanks to Dr. C. S. Beals, Dominion Astronomer, and to Dr. J. L. Locke, Chief of the Stellar Physics Division at the Dominion Observatory, for their courtesy in making the 15-inch telescope available to me.

National Research Council, Ottawa.
January 1957.

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COMMUNICATIONS
FROM THE
DAVID DUNLAP OBSERVATORY
UNIVERSITY OF TORONTO
Number 38

A NEW DIRECT-INTENSITY RECORDING MICROPHOTOMETER

By J. B. Oke

Introduction. The photometry of stellar spectra has always been hampered greatly by the vast amount of work required to reduce the easily obtained density tracing to an intensity tracing by using the proper calibration curve for the particular photographic plate.

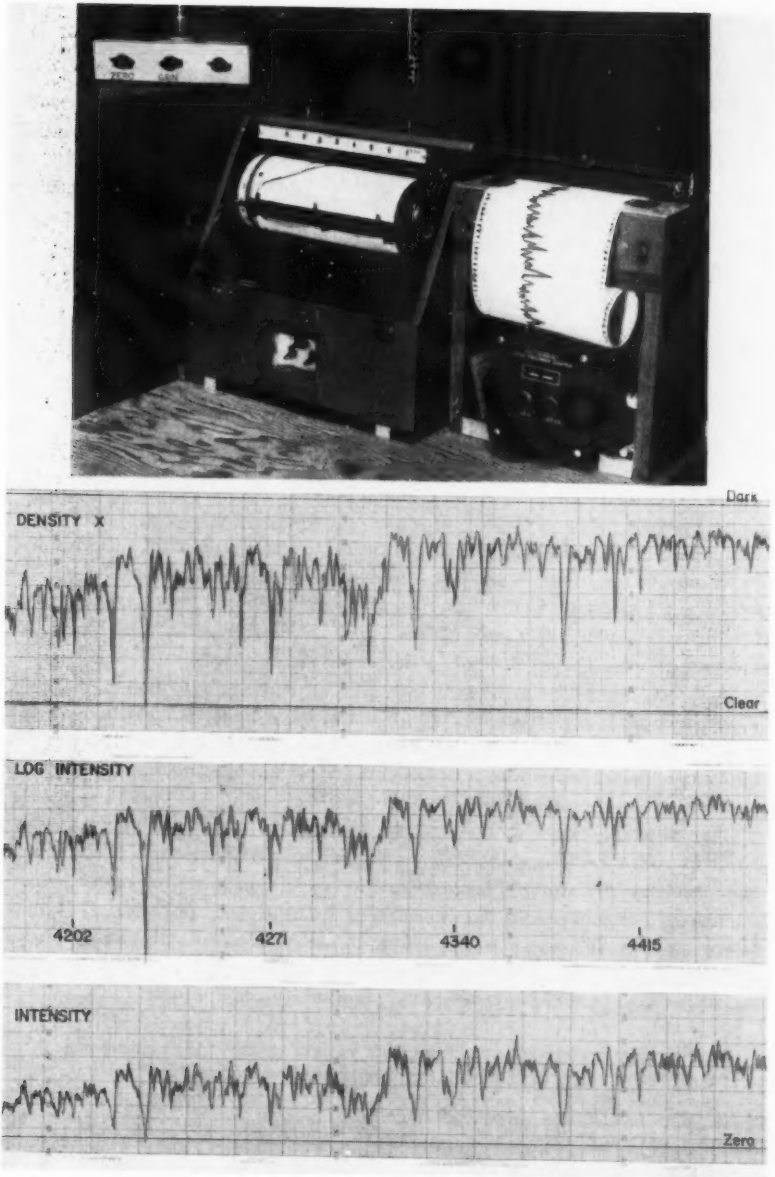
Some successful attempts have been made to minimize the reduction from density to intensity both electronically and mechanically. Perhaps the most elegant instruments yet built for the purpose are those constructed by R. C. Williams and W. A. Hiltner (1940) at the University of Michigan and by H. W. Babcock at the Mount Wilson and Palomar Observatories. These instruments produce intensity tracings directly by referring continuously by electronic, optical and mechanical means, to the proper linear wedge calibration plate. Another scheme has been devised at the Dominion Astrophysical Observatory by C. S. Beals (1944). Here a density tracing is made first and this tracing is converted manually and mechanically into a separate intensity tracing using the plotted calibration curve and a specially-constructed instrument.

Recently a new direct-intensity microphotometer has been put into operation at the David Dunlap Observatory. This instrument has three desirable features. Firstly, the optical part of the instrument is an ordinary microphotometer with a simple amplifier to provide the output voltage. Secondly, this output voltage is fed into a commercially built electronic instrument to which only minor mechanical alterations and additions need be made. Thirdly, the cost of the electronic instrument is not much greater than the cost of the usual type of recording potentiometer commonly used with microphotometers. The use of the basic electronic instrument for this purpose was first suggested by Dr. J. L. Locke of the Dominion Observatory.

The Instrument. The basic instrument used is a Model 1 Autograf *X-Y* Recorder built by the F. L. Moseley Co. This is simply an x-y curve plotter in which the x-signal rotates a drum and the y-signal drives a pen in the perpendicular direction. This instrument is modified into a data-correcting device by the addition of a Curve-Follower Adapter provided by the company. When the instrument is used as a curve follower any electrical signal X applied to the x-axis is transformed into a signal $Y = f(X)$ on the y-axis, where $f(X)$ is some known function inserted into the instrument as an electrically-conducting curve drawn on a sheet of graph paper. In our application, if the signal from the microphotometer, X, is put on the x-axis and if the conducting curve, $Y = f(X)$, inserted into the instrument is the relation between the x-deflection, X, and the corresponding intensity, I, where $I = Y$, then the instrument will generate the intensity, I, for every deflection, X. This intensity, I, can be read from the y-scale of the instrument or taken from the instrument as an electrical signal and fed into a suitable recording potentiometer which would produce the direct-intensity tracing.

Instead of using the electrical output we have modified the instrument in such a way that the required y-scale deflection can be used directly. To do this, a second pulley was attached to the pen servo-motor and this was used to drive an auxiliary pen-mechanism to the right of the instrument. See the figure for details. This auxiliary pen was made to record on a chart driven at constant speed, thus producing the intensity tracing directly. Since a 5-inch chart was to be used, the pulley on the servo-motor was made of such a size that full-scale deflection on the y-axis of the recorder (7 inches) corresponded approximately to full scale on the auxiliary chart (5 inches).

The Calibration Curve. To produce the required calibration curve it is necessary to obtain x-deflections of patches of known intensity on the photographic plate. Since the x-deflections are not conveniently recorded as an ink trace on the x-y recorder, it is desirable to record the deflections in some other fashion. This is done by connecting the output of the microphotometer not only to the x-axis but also through a voltage dividing resistance network to the y-axis; the signal voltage on the y-axis is arranged so that full-scale deflection on the x-axis corresponds to approximately full-scale deflection on the y-axis and auxiliary chart. A screwdriver calibration adjustment provided on the original instrument can be used to make the scale of the auxiliary chart exactly one half of the x-scale; the zero control for the recorder pen is used to make the zero points coincide. In this way, when the recorder is switched to "record",


Dark
DENSITY X
Clear
LOG INTENSITY
4202
4271
4340
4415
INTENSITY
Zero

the x-deflection is exactly duplicated, at half the scale, on the auxiliary chart; if the auxiliary chart is graduated from 0 to 10, as is usual, the two scales read identically. In this way the x-deflections for the calibrated patches on the plate can be recorded on the chart and the chart measured to give the data for the calibration curve. The calibration curve is then drawn with conducting ink and placed in the instrument. The switch is changed from "record" to "follow" and the intensity tracing is made. It should be noted that in the "follow" position the y-terminals are disconnected from the pen circuit.

When the x-scale and auxiliary chart scale have been brought into coincidence, no other adjustment can be made to the controls of the recorder. All gain and zero adjustments necessary when proceeding from one photographic plate to another must be made on the microphotometer amplifier, not on the recorder. It is therefore necessary to have a microphotometer amplifier with both a gain and zero control.

Application. The instrument described above is suitable for producing direct-intensity tracings by inserting into the instrument the calibration curve between the x-deflection, X, and the corresponding intensity, I. For some purposes it is desirable to make log-intensity tracings. This can be done simply by plotting the appropriate logarithmic calibration curve between X and log I. In this connection a convenient scale on the logarithmic tracing such as one inch equal to 0.4 in the logarithm can be arranged by using a calibration curve, not between X and log I, but rather between X and K log I where K is an appropriately chosen constant which can be determined for each instrument.

In the figure, a portion of the spectrum of γ Tauri is shown. The top tracing is the ordinary density tracing, the middle one a log-intensity tracing, and the lower one a direct-intensity tracing. The scanning speed was the same for all tracings.

Care must be taken to operate the instrument slowly enough that the curve is followed precisely. This is particularly important if the calibration curve is very steep. The decrease in speed compared to conventional recording is not great; in the instrument being described it is less than a factor of two. It is also necessary to have a microphotometer with no appreciable drift or sensitivity variation. If these points are kept in mind the performance of the instrument is completely satisfactory.

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CHUBB CRATER–A METEOR CRATER

By V. B. Meen*

Introduction. Chubb Crater is located at approximately 73° 40′ west longitude and 61° 17′ north latitude. It was first photographed from the air in 1943 and later in 1948. It was marked as a "crater" on the Povungnituk River sheet, No. 35 S.E.† but no explanation of its origin was offered. Early in 1950 the crater was called to the writer's attention by Mr. F. W. Chubb.

The writer is indebted to many individuals and institutions for advice, physical and financial assistance and the use of equipment. In 1950, the Globe and Mail Publishing Company supplied air transportation and their personnel, Kenneth W. McTaggart, correspondent, William Poag, pilot, and Andrew Gabura, flight engineer, were of great assistance in the field to the writer and his official assistants. These were Frederick W. Chubb and Robert C. Hermes, naturalist and photographer. In 1951 the financial assistance was supplied by the National Geographic Society, Washington. The personnel in addition to the writer were John A. C. Keefe, geophysicist, Nigel V. Martin, biologist, Richard H. Stewart, photographer, Leonard I. Cowan and F. W. Chubb, assistants.

Accounts of the 1950 reconnaissance (Meen, 1950, 1951a, 1951b) and a popular account of the 1951 expedition (Meen, 1952) have been published.

Physical Features of the Crater. Chubb Crater is located in the arctic zone of Quebec about 61 miles south-west of Wakeham Bay on Hudson Strait (figure 1) at about 1,700 feet elevation above sea level. The immediate vicinity is reasonably flat with a few scattered gentle elevations. About twelve miles to the north a range of hills rising to 2,000–2,100 feet marks the horizon.

From the air and from the rim itself, the crater appears quite circular. A transit and triangulation survey showed, however, that it is slightly elliptical about a long axis bearing ca. N. 80° E. The dimensions‡ are as follows:

	Crater–rim to rim	Crater lake
long axis	11,500 feet (2.18 miles)	9,300 feet (1.76 miles)
short axis	11,000 feet (2.08 miles)	8,925 feet (1.69 miles)

*Head, Division of Geology and Mineralogy, Royal Ontario Museum, Toronto.

†Nat. Top. Ser., Dept. Mines and Res., Sur. and Eng. Branch, Hydrographic and Map Service, Canada.

‡These figures differ slightly from any published previously but are the result of careful study of all available data.

FIG. 1—Index map showing the location of Chubb Crater

The highest points (figure 2) of the rim are on the east and stand about 550 feet above the level of Museum lake.† The lowest part of the rim is not quite diagonally opposite but is in the south-western quadrant. Although the general elevation of this part of the rim drops to about 250 feet, a rift or gully 725 feet east of the cairn W_2 (figure 2) has an elevation of only 200 feet.

The rim is broadest on the east and narrowest on the west (figures 2 and 4). In general it may be said that it is so broad that if one is standing on the crest of the rim at any part of the crater, it is impossible to see down into the crater or down into the outer plain. This flatness gives over to an ever-steepening slope until a maximum is reached. This seems to be 40° to 45° internally and about 25° externally.

The foregoing statement requires some modification. In the case of

†The elevation of Museum lake is about 1,670 feet determined by aircraft altimeter with reference to Fort Chimo. Elevations of points on the west and south-west sections of the rim were determined by levelling. However, bad weather, coupled with difficult terrain, slowed the work to such an extent that elevations on the east rim were determined by reference to an assumed elevation for E_2 (figure 4). This elevation was estimated by the writer at 2,220 feet by aneroid barometer in 1950.

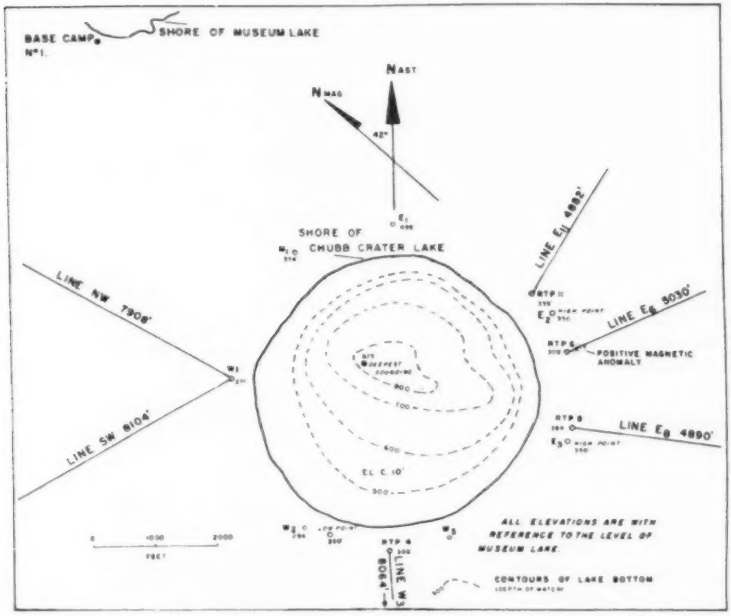

FIG. 2—Map of Chubb Crater showing the location of magnetometer survey and the contours of the bottom of Crater lake.

the external slope, the steep 25° angle is maintained down to an elevation of about 240 feet above Museum lake. Thereafter the slope is very much more gentle, averaging about a 2 per cent. grade. In the case of the internal slope of 40°–45°, it is lost to view after it enters the contained lake. The elevation of the crater lake is about 1,680 feet or about ten feet above Museum lake.

Sixteen soundings (figure 2) were made and these indicated that the slope of the rim was continued with no apparent change to a depth approximately equal to the height of the rim above the particular location (figure 3). The slope then changes very rapidly so that the bottom becomes a gentle basin-like depression with its deepest part somewhat north of the centre. A shallowness in the eastern portion of the bottom may be due to a slumping of considerable magnitude in the adjacent east rim.

The greatest depth measured was 825 feet. This figure, added to the

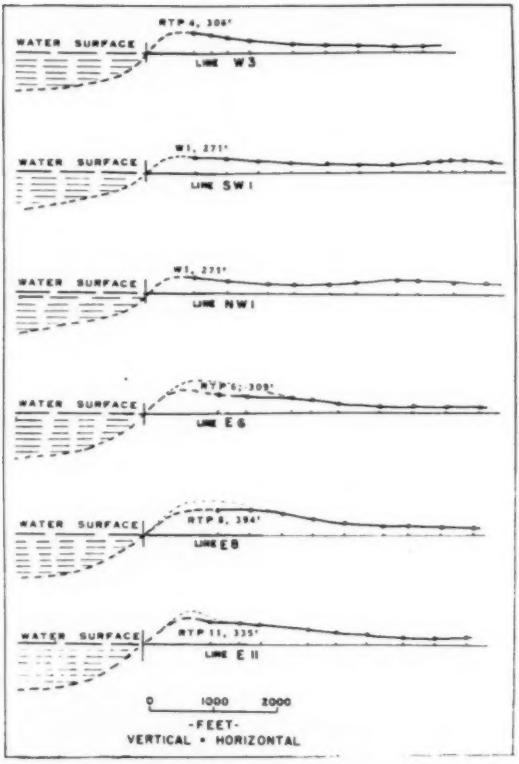

FIG. 3—Profile of Chubb Crater rim along the survey lines.

maximum height of the rim above the water of about 540 feet, makes a total depth for Chubb Crater of about 1,365 feet.

As mentioned earlier, the rim is composed of granite in place with a sprinkling of fragments on top and considerable talus on inner and outer slopes. The bedrock of the rim shows a most interesting jointing pattern. Three sets of jointing appear. One set dips radially outward at about 15° and may be observed at many parts of the crater rim. A second set of jointing is always radial to the circle of the crater and the third is at right angles to the other two, in other words, circumferal. Many of the joints have been opened up to widths of a foot or more. This may have been brought about by the expansion in volume as the

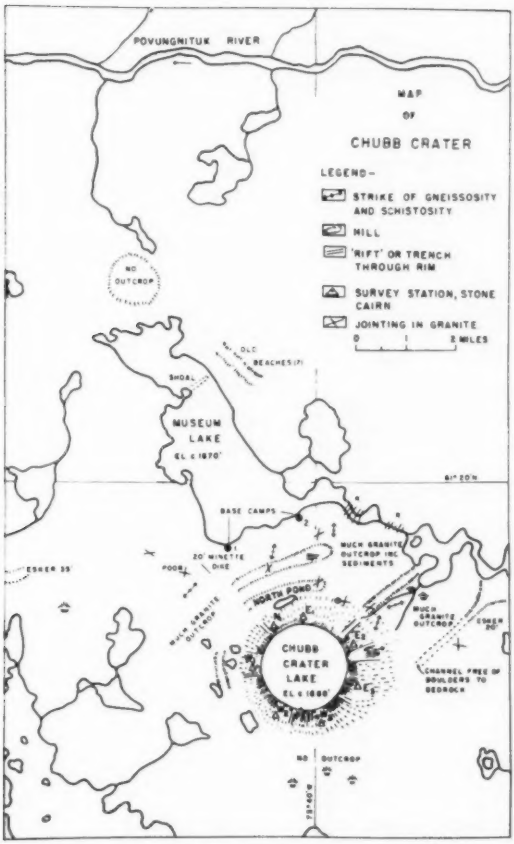

FIG. 4—Generalized geologic and topographic map of Chubb Crater and vicinity.

rock was raised to its present position or it may have been caused by frost action. Most of the fragments show considerable rounding as a result of exfoliation or grinding caused by frost heaving, and, in places, there is a considerable mantle of boulders.

It has been pointed out that the elevation of the rim is not uniform and that it is lowest in the south-west quadrant. In addition to general irregularities, there are also pronounced trenches or rifts which cut radially through the rim. These are not regularly spaced (figure 4) but

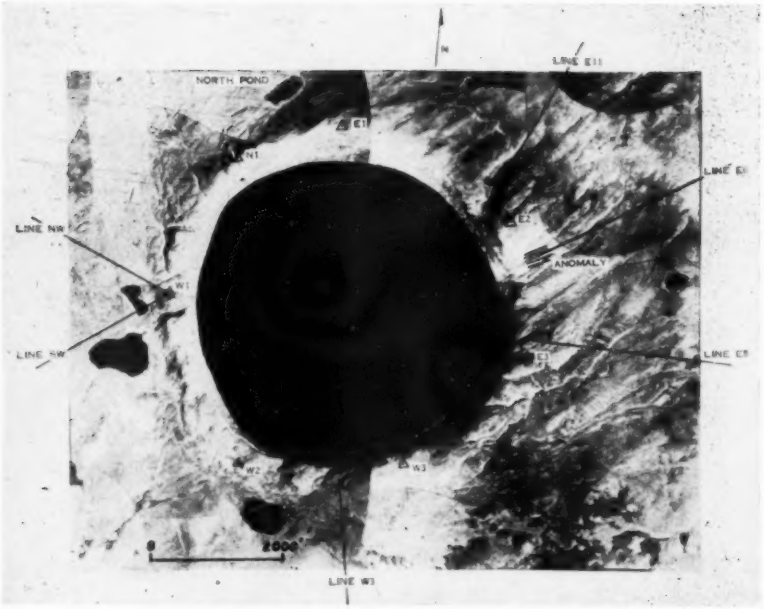

FIG. 5—Mosaic photograph of Chubb Crater showing the effects of glaciation, the location of survey points and the magnetometer survey—R.C.A.F. photograph RE 7767–2 with additions.

are, nevertheless, found all around the rim. They range in depth from twenty feet to two hundred feet but most seem to have a depth of forty to sixty feet. Two rifts, two hundred feet deep, transect the highest part of the rim, that is in the east. What appears to be the lowest part of the rim is the bottom of a rift in the south-west quadrant with an elevation of two hundred feet. This is the portion mentioned in earlier reports (Meen, 1950, p. 175; 1951b, p. 55) and estimated then to be about 260 feet.

Harrison (1954) has published a mosaic of aerial pictures (figure 5) which indicates that the crater rim has been subjected to glaciation. He points out that the deep rift north of station E_2 is not straight nor quite radial to the crater, and in addition is U-shaped. The writer agrees that this evidence indicates that the crater rim has been glaciated, and we can conclude that this rift, and probably others, have been modified by the movement of the ice.

On the outside of the rim, and forming radial continuations of the larger rifts, are ridges of fragmental material. One of these, that extending from the large rift north of station E2, extends across the plain for nearly 2½ miles, and forms a peninsula in a small lake (figure 4).

It is Harrison's conclusion that these trenches are simply valleys through which the ice, which flowed across and through the crater, leaked out into the surrounding terrain. However, several of these are oriented at such angles, and do not appear to be modified by glacial action, that the writer retains the conviction that the trenches or rifts were produced by extra forces in the explosion carrying away material from the rim and depositing this material in a radial pattern as ridges in the outer plain. Some of these rifts may later have been modified, even modified to a considerable extent, by the action of the moving ice, and the ridges themselves may have been greatly enlarged by the deposition of glacial moraine thereon.

In earlier publications (Meen, 1950, p. 176 and 1951b, p. 54) mention was also made of ridges of granite bedrock which appeared to circle the crater rim (figure 4). There was not time to locate accurately the ridges and determine their elevations above Museum lake. However, such ridges are present, particularly on the north flank of the crater but, although concentrically arranged, are not continuous. They are bedrock and seem to be jointed radially and tangentially to the crater. The ridges furthest out from the crater exhibit less strong jointing.

Although these ridges project only 35–50 feet above the surroundings, it should be borne in mind that they form part of the area which has been uplifted in the explosion and that in reality they stand 185–200 feet and 135–150 feet, respectively, above the datum level of Museum lake. It is not to be construed, however, that the areas between the rim and the satellite ripples are filled with fragmental material down to the datum plane. On the contrary, rock outcrop appears in many places between and beyond the ripples. They simply indicate loci of particular uplift.

It is my opinion still that these ridges are ripples surrounding the crater and represent granite-gneiss pushed up by the explosion. Possibly the spacing is significant. From the centre of the crater to its rim is about 1.1 mile, to the first major ripple about 1.7 mile and to the second ripple about 2.1 miles.

In earlier publications (Meen, 1950, p. 176; 1951b, p. 56) mention was made of small ponds in the vicinity of the crater and it was suggested that they might be small craters. In the more detailed study of 1951, it was decided that these ponds were accidental catchment basins in the fragmental debris on the flanks of the rim. Only one was sounded. This

was North pond on the north slope, situated about 240 feet above Museum lake. The maximum depth was determined as 27 feet. There was nothing to suggest that the depth of the other ponds might be greater. In fact, looking down from the rim they appeared to be more shallow but there was no time available to take the sounding gear to them.

A determination of the transparency of the crater lake was made. A secchi disk was lowered near the centre of the crater at approximately noon with the water surface nearly calm. It was visible to the unaided eye to a depth of 115 feet (35 metres). In spite of the conditions and the obliquity of the sun's rays because of latitude, the transparency of the water compares favourably with that of the waters of other clear lakes and is exceeded only by Lake Masyûko, Japan, and Crater lake, Oregon.

Observations made by Martin on the crater lake and adjacent lakes are summarized in Table I.

TABLE I

SUMMARY OF LIMNOLOGICAL OBSERVATIONS ON CHUBB CRATER LAKE AND NEIGHBOURING LAKES

Lake	Approx. maximum depth	Surface temperature	Bottom temperature	pH (surface)	Oxygen (surface)*	Secchi disc value
	feet	°C.	°C.		mg./l.	feet
Crater	825	{July 31: 2.9 {Aug. 18: 3.9	July 31: 2.6 (from 9′ to 400′)	July 31: 6.5 Aug. 11: 6.6	July 31: 14.4 Aug. 11: 15.2	Aug. 11: 115
Museum	30	Aug. 16: 7.8	Aug. 16: 8.4	Aug. 4: 6.4	—	—
North Pond	27	—	—	Aug. 11: 6.6	Aug. 11: 10.8	Aug. 11: 17

*Oxygen bottle was lost on first attempt to take deep water samples.

A gallon of water from the crater was brought back and the analysis is given in Table II.

TABLE II

MINERAL ANALYSIS OF SURFACE WATER TAKEN FROM CHUBB CRATER LAKE, QUEBEC, AUGUST 18, 1951* IN PARTS PER MILLION

Total solids	less than 20.0	Aluminium	1.60
Organic matter (loss on ignition)	less than 15.0	Calcium	less than 1.00
		Sodium	0.30†
Hardness	1.70	Potassium	less than 0.02
Alkalinity	1.20	Magnesium	less than 0.10
Nitrogen as N	0.83	Silicate	2.40†
Nitrate	0.08	Sulphate	0.70
Nitrite	0.00	Chlorides	0.00
Iron	less than 0.04	Phosphorus	less than 0.001

*Analysis 143, May 26, 1952, Dept. of Pub. Health, Prov. of Ontario.
†The silicate and sodium figures are probably too high because the sample was stored in a glass bottle for several months.

During the course of the field work, two samples of water were prepared, one from the crater lake and the other from Museum lake. In each case, four gallons of water were evaporated down to approximately 300 ml. in volume. These were brought back and spectrographic analyses were made for nickel by the Provincial Assayer, Department of Mines of Ontario.

It was found that both samples contained a trace of nickel. Estimates from the spectrographic analyses indicated that the four gallons of crater lake water contained 0.0015 mg. nickel and the four gallons of Museum lake water contained 0.0011 mg. nickel.

Specimens of boulders of gabbro, diabase, etc. from the area were analysed in similar manner and the nickel content ranged from 0.02 to 0.25 per cent. This is of the same order as the nickel content of similar rocks from varied locations, chosen from the collections of the Royal Ontario Museum. It is possible that the spectrographic trace of nickel in the water samples may be attributable to leaching of nickel from such boulders.

A small 6-inch Ekman dredge modified for deep water work, after D. S. Rawson, University of Alberta, was lowered to the bottom in the crater lake to depths up to 400 feet but no samples were obtained. It would seem that the fragments on the bottom were too large, or the material was too hard packed, or the dredge was too small. Since samples were obtained from the bottom of North pond, it would seem that in all probability the fragments in the crater were too large.

Since there are numerous ponds located on the crater slopes high above the crater lake and these drain into the lower outer lakes without seeping into the crater, it does not seem likely that there is a connection between the crater and the outer waters which would pass *beneath* the ponds on the flanks.

Geology. The area is underlain by rocks of apparent Precambrian age. In the immediate vicinity of the crater the bedrock is an almost white muscovite-biotite granite with a slight gneissic structure. Although the most frequently obtained determination of the gneissosity is N. 15°–20°E. astronomic, readings of great variety are obtained, ranging from N. 85°W. to N. 40°E. The variation is probably due to the lack of a pronounced foliation.

An easterly trending band of sediments or volcanics older than the granite, extends across the area to the north. The south boundary is approximately the Povungnituk river which lies about five miles north of the north end of Museum lake. None of the party was able to visit this

formation. However, it can be observed to the north as ridges extending east-west across the otherwise nearly flat terrain, and its contorted nature is readily identified in aerial photographs. It is not considered that this band of rocks has any connection with the origin of the crater.

The only non-granite rocks found in place near the crater were two or three minette dikes and a few inclusions of biotite schist. The largest of the latter is located about 1,500 yards south-east of Base Camp No. 2 (figure 4) and is about 200 to 300 yards long in a north-east to south-west direction with schistosity bearing N. 80°W. with vertical dip. No dikes were seen close to the crater rim. The nearest observed is about one-half mile west of Base Camp No. 1. It is about 20 feet wide and strikes N. 60°W. The granite into which the dike has intruded shows poor jointing in two directions at N. 10°E. and N. 60° to 80°E. It will be noted that the strike of the dike does not parallel either set of jointing and the intrusion of the dike most certainly preceded the jointing.

The area has been glaciated. No striations were observed but some fluting was seen. There is very little material which might be referred to as soil. The surface is covered almost completely by boulders. Most of these are of granite similar to the underlying rock. There are also occasional scattered boulders of quartz-diabase, peridotite, lamprophyre, biotite schist, quartz porphyry and quartz. With the exception of the lamprophyre, and biotite schist, none of these were seen *in situ*.

Away from the crater, the boulders are, for the most part, well rounded. This is particularly true in the areas between outcrops of granite. It is possible that some of the rounding is due to grinding caused by frost action and if this is the case, then some of the boulders may represent bedrock beneath and not have been carried to the site by the glacier. However, much of the material was glacially deposited.

From ground study and by a study of aerial photographs, there appears to be a lineation, caused by glaciation, of parallel rock ridges and morainal ridges bearing about north-east.

Two eskers (figure 4) were visited. One lies about four miles north-west of the crater and is about 35 feet high and extends for several miles further to westward, according to aerial photographs. It is about 200 feet wide and composed of coarse gravel. The other is located about two miles east of the crater rim. It is several hundred yards long and its eastern extremity, as seen from a distance, is fan-shaped.

The age of the crater can be determined only in a general way. Because of its most remarkable symmetry and lack of any apparent filling, it was originally stated (Meen, 1950, 1951a, 1951b), that the crater could not have preceded any appreciable ice movement. Because of the many

"perched" boulders which may be observed on the crater rim, the writer concluded that ice may have covered the area at the time of the explosion and that, as a result, fragments might have been left in this characteristic condition.

However, in the summer of 1953 the Royal Canadian Air Force re-photographed the crater and the immediate vicinity using vertical photography. The mosaic photograph (figure 5) which was constructed as a result, leaves no doubt that the crater has been overridden by a continental glacier. This has been pointed out by Harrison (1954).

The lack of in-filling of the crater is explained by Harrison on the basis that the crater lake would freeze to the bottom and thereafter the glacier would slide over it. He suggests too that the prominence of the rim might deflect the glacier to left and right so that a minimum of ice would pass over the crater rim itself. This would seem quite possible.

An age for the crater, pre-glacial or at least earlier than the last advance of the ice, would account for the presence of well-rounded boulders mixed with more angular fragments, the presence of boulders of diabase, etc., although no such rocks were seen in place, and could account for the complete lack of any material of meteoritic origin even if any had survived the explosion.

North-east of the shear (shown in figure 4) on the east side of the crater is a swamp through which runs a fast-flowing creek which seemed to rise to the west toward the large rift in the eastern rim. Whether it rises from the ground as a creek or is built up by the steady accumulation of melt water from the slopes, was not determined.

On the south side of the swamp is evidence of a former river of much greater size. In places the bed of this former stream is swept clean to bedrock and walled on either side by a six-foot thickness of moraine, mostly boulders. In other places the bottom is built up across as a ridge. Its upper end appears to be connected with a rift south of E3 (figure 4) in the crater rim, while its lower end is an esker and beyond that what appears to be a fan of detrital material (page 146). This seems to have been the course of a sub-glacial river. Time did not permit the exploration of this old river bed which in places is up to 200 yards in width. The complete absence of fragments in the trench-like portions indicates that the force of water over these portions must have been tremendous. The source of such a river could have been only the crater itself.

Reconstructing the evidence then it would seen probable that the crater was produced prior to the end of the Ice Age. It was overridden by ice, at which time it would have been filled with ice, and the rim was grooved in a south-west to north-east direction. Some of the rifts

were modified by the ice movement. When the ice melted the crater became a lake and it is possible that the rifts were still cemented shut by ice. As the temperature increased, one of these gave way, allowing the dammed-up water of the crater lake to flow out as a mad torrent. It is possible that the level of the lake was lowered by 100 feet or more in this action. A calculation on this basis indicates that the weight of the water so released would approximate 270 million tons. If rotting ice still existed on the east flank of the crater, then the water flow may have been contained as an internal river for the short distance to the level plain where the detrital material was dropped first as great boulders, then gravel in the form of an esker and further away as a fan of apparently sandy material. The latter part was not examined.

To sum up the geology of the vicinity: The crater is located in an area of apparently Precambrian granite which is slightly gneissic. Other rocks, igneous and sedimentary, are not present in significant amount and have no structural relationship to the crater. There is no evidence of vulcanism, no karst topography, and no possibility that the hole could be a glacial sink. Contrary to earlier statements that the crater was post-glacial in age, it is apparent that it is at least earlier than the last advance of the ice.

Geophysical Evidence. The field work of the geophysical survey was carried out by J. A. C. Keefe, assisted by L. I. Cowan. The results so obtained were later worked up by Keefe, S. H. Ward and J. T. Wilson. Their report and interpretation of the data follows:

REPORT ON SURVEY OF VERTICAL MAGNETIC INTENSITY NEAR CHUBB CRATER, JULY–AUGUST, 1951.

By J. A. C. Keefe, S. H. Ward and J. T. Wilson

Geophysics Laboratory, Department of Physics, University of Toronto

During the stay at Crater lake from July 25 to August 21, 1951, a magnetic survey was made by Keefe in the vicinity of the crater along as many radial lines as time permitted after he had made the topographical surveys. These lines are shown in figure 2. The survey was executed with an Askania vertical intensity magnetometer with scale constant of 25.6 gammas per scale division, using either one of the two magnets as required.

The field procedure was as follows: a base station W_1 was selected and given an

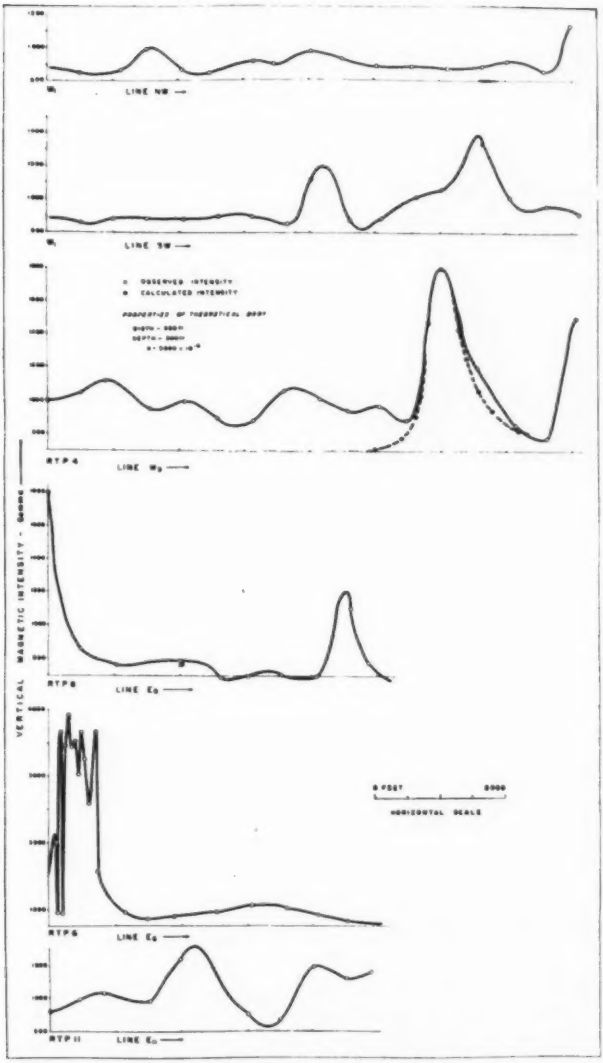

FIG. 6—Magnetic profiles along the principal surveyed lines, see figures 2 and 5.

arbitrary value of vertical intensity of 880 gammas. Along lines SW and NW which extend out from this station, readings were taken at intervals of approximately 500 feet. To enable a correction to be made for diurnal variation, the main base station or an auxiliary station was reoccupied approximately every hour. A similar procedure was followed along line W_3 extending from base station RTP4 and for the group of lines in the north-east quadrant which were tied to station RTP6. It had originally been intended to tie all observations to base station W_1 but shortage of time caused by bad weather and the long distance involved prevented this. Consequently the differences in the values of vertical intensity at the three base stations are uncertain by the amount of the diurnal variation which occurred between the times when they were occupied.

Therefore, the datum level of intensity plotted for the three groups of lines differ by a small undetermined amount but, apart from this, any one reading is believed to be accurate to within 25 gammas.

The profiles obtained along the longer lines are shown in figure 6 but it must be realized that the station interval was so great that the continuous lines shown joining the observed points can be regarded only as approximate interpretations.

Several zones of anomalous intensity were located whose exact shape and maximum intensity depends upon the interpretation given to the sparse field observations. Striking anomalies occur on each line except NW. The most pronounced, occurring on line E6, was the subject of a somewhat more detailed survey during the last three days of the expedition when four additional short lines were traversed with stations at intervals as short of 50 feet. The results, which were all referred to base station RTP 6, are shown in figure 7. Approximate contours, whose position in places depends largely upon arbitrary judgment, have been added at 1000 gamma intervals.

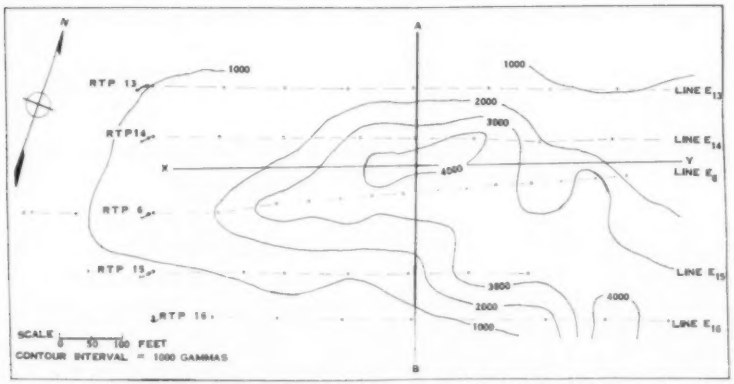

FIG. 7—Magnetic contour map of the anomaly on the east rim.

The data available clearly suggest that the long axis of this anomaly strikes about N. 70°E. astronomic which coincides reasonably well with the general trend of foliation (about N. 50°E.*) in the granite and granite-gneiss, and excellently with the strike of the shear which exists at this same location.

*Foliation of this bearing was seen only rarely, the usual being N. 15–20°E. (p. 145): V.B.M.

The limited magnetic and geological data preclude the possibility of making any precise interpretation, but it is possible to make rough approximations to the types of body which might be causing this anomaly if certain simplifying assumptions are made.

For example, it has been calculated that a similar anomaly (figure 8) could be caused by a dike of semi-infinite extent, 150 feet wide, with its upper surface 50 feet below the ground dipping 65° south and consisting of about 10 per cent. magnetite disseminated through silicate rock. However, the fluctuations of a few thousand of gammas occurring along line E6 in this vicinity between stations less than 50 feet apart indicate that at least parts of the anomalous body extend either to surface or very close to it and correspondingly smaller concentrations of magnetite would therefore be sufficient. As no fragments or outcrops of any basic igneous rock or meteoritic material were found in this vicinity it is considered that the anomaly may well be due to a band in the local country rock containing a few per cent. of magnetite. Anomalies of this order of magnitude have been found frequently in northern Manitoba associated with concentrations of 1 to 10 per cent. of magnetite in the country gneisses.

It is believed that all the other observed anomalies, although less work was done on them, could be explained in a similar manner. For example, the anomaly at 6,000 feet on line W_3, could correspond with that caused by a semi-infinite dike 6,000 feet wide with its upper surface 2,000 feet deep containing 2 per cent. magnetite. No evidence found to date suggests that basic intrusive bodies or meteoritic fragments of any such dimensions exist in that area.

The conclusion to be drawn from this work is that, although the limited amount of data does not preclude the possibility that magnetic anomalies may exist which are caused by meteoritic fragments, no anomalies have yet been found which could

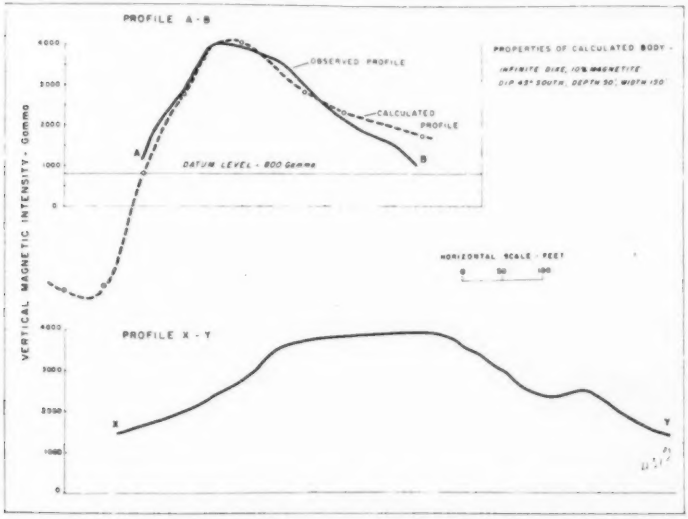
PROFILE A - B
OBSERVED PROFILE
CALCULATED PROFILE
PROPERTIES OF CALCULATED BODY -
INFINITE DIKE, 10% MAGNETITE
DIP 65° SOUTH, DEPTH 50', WIDTH 150'
DATUM LEVEL - 800 Gamma
VERTICAL MAGNETIC INTENSITY - Gamma
HORIZONTAL SCALE - FEET
PROFILE X - Y

FIG. 8—Magnetic profiles along sections XY and AB in figure 7 with a profile calculated for a hypothetical dike.

not be satisfactorily explained by slight concentrations of magnetite in some bands of the country rock. Anomalies resulting from such slight concentrations are well known in other parts of the Canadian Shield.

It is to be noted that the authors of the report conclude that the anomaly outlined by Keefe may be caused by other than meteoritic fragments. However, the location of the anomaly beneath the eastern rim where such fragments might be expected to be buried (see p. 153) seems to be an interesting coincidence. Although no fragments of meteorite were found on the surface, it is none the less possible that such fragments might still exist close beneath the surface, where they have been preserved from glacial removal, and from chemical deterioration because of their position in the permafrost.

Evidence of Meteoritic Origin. A search was carried on continuously for fragments of a meteorite. Rusty boulders in countless numbers were examined in the field and many in the laboratories. All were found to be one of lamprophyre, gabbro, diabase, peridotite, pyrite-bearing porphyry and some others. All were of terrestrial origin.

Mine detectors (U.S. Army SCR–625) were found to be too sensitive, reacting readily to granite boulders and, of course, more readily to the rusty boulders. A large magnet was dragged over the few areas where there was sand or gravel, in the search for metallic droplets similar to those found at Barringer Crater, Arizona. None was obtained.

The writer is convinced that Chubb Crater was caused by the impact of a giant meteor. However, since no fragments of meteorite, no metallic droplets, and no glass (lechateliérite) were observed, it seems appropriate to gather together the observations and data which have been enumerated to substantiate this conviction.

There is no evidence whatever of vulcanism, and a theory of volcanic origin is completely untenable. Since the rock is granite, it is not possible to conceive of karst topography as providing the origin. Since the rim is solid rock and *raised* above the surroundings, it cannot be a glacial sink, nor could it indicate the site of an eroded plug. This leaves meteoritic origin as the only recognized possibility. Why, then did we not find fragments of meteorite, droplets of metal or of glass?

No fragments of meteoritic material have been recognized. The following suggestions are put forward to account for this.

1. The heat generated by the explosion may have vaporized the whole mass.
2. Fragments and/or droplets of metal may have survived but:
   a. have fallen on the surface of ice supposing that the meteor struck while the area was blanketed by the continental glacier, or

b. have been swept away by the movement of the continental glacier which flowed over this area subsequent to the explosion.

3. Some of the fragments and/or droplets may have survived and become mixed with the rock debris at the site. The boulder till is saturated with water and it might be expected that such fragments if metallic would deteriorate rapidly. If stony, the frost action in the arctic zone would cause the loss of any glass coating and their probable prompt deterioration.

4. In spite of the above, if any fragments had survived, the terrain is so bouldery that a serious inspection of all the boulders within a representative area is completely out of the question. Hence rusty coloured fragments could be mistaken for rusty gabbro, peridotite, etc.; grey fragments pass for granite boulders and even fragments of black glass be mistaken for the black lichen which is so prevalent on all boulders and outcrop.

Despite the lack of such conclusive and incontestable proof as fragments of the meteor, there is nevertheless some evidence of a positive nature.

The crater has every appearance of any explosion crater. It is almost completely circular. Its slight ellipticity agrees very well with the experimental data of Rinehart and White (1952, p. 14) for a missile striking at an angle of incidence of about 45°. The jointing of the rock and the great rifts through the rim, with their sometimes attendant ridges of fragmental material stretching radially beyond the rim, add further evidence. In fact the inclination of the jointed granite is extremely similar to the upturned strata of sandstone and limestone at the Barringer Crater. The high broad rim at one end of the slightly elliptical crater, and the lower narrow rim at the opposite side, is further evidence of such an explosion and agrees with the data obtained by Rinehart and White.

These workers have also shown (p. 16) that craters produced by oblique impact have a steep slope on the side from which the missile came and a reasonably shallow slope opposite to it. This situation is quite evident at Chubb Crater where the western slope is quite steep, about 45°, and the diagonally opposite slope is about 30°.

The presence of a magnetic anomaly under the highest and broadest outthrow part of the rim, while not conclusive evidence of the presence of some buried fragments of meteorite, seems to be more than merely coincidental. The spotiness of the readings referred to by Keefe *et al.* (p. 151) would indicate that the material which is producing the anomaly is fragmentary in form.

Finally, there are the deductions which may be made from a study of the

ratio of the height of the rim and the depth of the crater to the diameter of the crater.

Baldwin (1949, pp. 131–8) has shown that terrestrial explosion craters, meteor craters and lunar craters, all obey two laws: one which relates the rim height and the diameter of the crater, and the second which relates the depth and the diameter of the crater. He therefore concludes that all these craters have explosion origin.

The equations which he developed for these relationships are as follows: $E = -0.097D^2 + 1.542D - 1.841$ (p. 136)

$D = 0.1083d^2 + 0.6917d + 0.75$ (p. 131)

where E = log rim height (feet); D = log diameter (feet); d = log depth (feet).

Fitting the appropriate measurements of Chubb Crater into these equations we get: average diameter rim to rim = ca. 11,250 feet, $\therefore D = 4.0511$; depth from average rim height = ca. 1,215 feet, $\therefore d = 3.0845$; average rim height = ca. 400 feet, $\therefore E = 2.6021$, and therefore:

$E(2.60) = 2.81$; $D(4.05) = 3.91$.

These calculations, particularly the second, show that the dimensions of Chubb Crater agree very well with the expected relationship for an explosion crater as shown by Baldwin. The agreement is even better shown by reference to the graphs which he drew up to illustrate these relationships (Baldwin 1949, pp. 132 and 137).

The measured height of the rim is undoubtedly less than the original height as a result of loss by glacial erosion, and the measured depth is undoubtedly less than the true depth because of back-falling of fragmented material and the deposition of glacial debris. Any correction of these dimensions, therefore, would be in the form of increase and would therefore increase the values of E and d. Each increase in this way would serve to bring the respective equations into closer harmony.

We can conclude, therefore, that Chubb Crater is an explosion crater and because of its tremendous size is due to extra-terrestrial forces. The only such force so far proven to be capable of producing such craters is the impact and explosion of a meteor. No evidence of any sort has been observed which supports a theory of any other origin.

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CANADIAN SCIENTISTS REPORT

IV. ON THE INTERPRETATION OF STELLAR SPECTRA

By Anne B. Underhill

The only information we may obtain about a star is that conveyed to us by its radiation, for the radiation that emerges from it and impinges on the earth is the only direct contact we have with a star. From our knowledge of the possible interactions between radiation and matter (established by experimental and theoretical studies) we attempt to deduce information about the physical conditions in the stars by analysing their spectra. The stellar radiation which we receive reaches us after traversing the outer layers or atmosphere of the star, the space between the star and the earth, and the earth's atmosphere. All these media may interact with the radiation and alter the radiation from its initial form. In what follows we shall concentrate our attention upon the modifications of the radiation introduced by the stellar atmosphere, and we shall ignore the much lesser effects of the interstellar medium and of the earth's atmosphere. We shall analyse the observed modifications and indicate how one may deduce the physical state and chemical composition of the outer layers of a star from a stellar spectrum.

A stellar spectrum is a record of intensity or brightness of light coming from the star in each wave-length or colour. The spectra of individual stars differ in appearance quite considerably, some spectra containing many narrow absorption lines while others are mainly continuous with only a few absorption or emission lines. Some characteristic spectra are displayed in a recent article in this Journal (vol. 44, p. 129, 1950).

Careful comparison of many stellar spectra reveals that all spectra are made up from three units. First there is a continuous spectrum in which the intensity of light varies slowly with wave-length. Secondly, there are absorption lines which may be many or few in number, strong or weak, and of different shapes and which may appear at different wave-lengths. Thirdly, emission lines occur in a few spectra. The vast majority of stellar spectra contain only absorption lines in the wave-length range usually observed between 3200A. and 6700A.

The three component parts of stellar spectra are illustrated in figure 1 which gives a schematic representation of an intensity tracing from a stellar spectrogram. Here the intensity of light at each wave-length is plotted in the vertical direction and the wave-length is plotted in the horizontal direction. An absorption line will appear dark in the

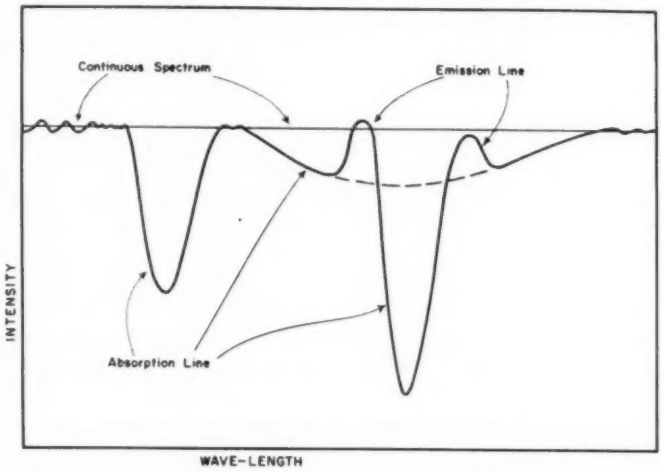

FIG. 1—Schematic representation of an intensity tracing from a stellar spectrogram.

spectrum because at these wave-lengths less light reaches us than from the neighbouring continuous spectrum, while an emission line will appear bright because more light reaches us than would normally be the case. The continuous spectrum is the basic component of the stellar radiation and the absorption and emission lines are formed as a result of the interaction of matter with the radiation as it passes through the outer layers of the star.

A star is entirely gaseous, and the stellar atmosphere (which is the region in which the stellar spectrum is formed) comprises but a minute part, being usually less than one-thousandth of a stellar radius in depth. Consequently the curvature of the atmospheric layers is small in comparison to their thickness, and nearly all stellar spectra may be interpreted in terms of a plane-parallel layer of gas of constant chemical composition. Since *absorption* lines normally appear in stellar spectra, it is clear from elementary physics that the outer layers of the atmosphere must be cooler than the inner layers where the continuous spec-

trum is formed. This means that the temperature increases inwards in normal stellar atmospheres. Furthermore, because of the detailed shape of the absorption lines and because normal stellar spectra do not change over periods of many years, it may be assumed that normal stellar atmospheres are in mechanical equilibrium under the gravitational attraction of the mass of the star. The spectra of a few stars, notably the supergiants, are peculiar in some respects, and some of the unusual features observed suggest that the atmospheres of these stars are not in mechanical equilibrium.

When we obtain a stellar spectrum we are analysing that part of the radiation from a star that is sent in our direction. This radiation, or *flux* as it is called, is made up of many photons of light. Each photon has an energy $E = hc/\lambda$, where h is Planck's constant, c is the velocity of light, and λ is the wave-length of light. The light of different wave-lengths is sensed by our eyes as light of different colours; thus light of wave-lengths near 6500A. appears red, while light of wave-lengths near 4500A. appears violet to the normal eye. By specifying the wave-length of the light, we are, in virtue of the above equation, specifying the energy of the photons. In what follows we shall speak of radiation of a given wave-length whenever we mean the flux of radiation of a given energy per photon.

A spectrum is then a record of the number of photons of each energy existing in the flux of radiation from the star. When the intensity at a wave-length λ_1 is greater than that at another wave-length, λ_2, it means that per unit time we receive more photons of energy $E_1 = hc/\lambda_1$, than we do of energy $E_2 \pm hc/\lambda_2$.

As we have seen, the material of a stellar atmosphere is gaseous. The constituents of the gas may be atoms, ions, diatomic molecules or radicals. The number of each depends not only upon the chemical composition of the atmosphere, but also upon the temperature and pressure. Thus high pressures and low temperatures favour the formation of molecules and radicals, while low pressures and high temperatures favour the formation of ions. At the lowest stellar temperatures, around 2,000°K., most of the atoms are neutral, and many are combined in molecules and radicals. At the temperatures of the O stars, around 30,000°–40,000°K., there are neither molecules nor radicals left, and almost all the atoms have lost at least one or two electrons.

Now, the study of physics has shown that each kind of molecule, radical, atom or ion will interact with radiation in a specific manner *characteristic of itself alone*. For instance, neutral hydrogen atoms will emit or absorb light of only certain wave-lengths; neutral iron atoms

emit or absorb certain other wave-lengths; once-ionized iron atoms emit or absorb another group of wave-lengths. Each group of characteristic wave-lengths is called a spectrum, and physicists have tabulated the spectra of most of the common atoms, ions, molecules and radicals. It is clear that to determine whether a certain molecule, radical, atom or ion is present in a stellar atmosphere, all we have to do is to look at a stellar spectrum and see whether the characteristic spectrum of the molecule, radical, atom or ion in question is present. If the characteristic spectral lines are present, we know that that atom is present. If the characteristic spectrum is not visible we conclude that there are not enough atoms of that kind present to be observed.

The strength of an absorption line in a stellar spectrum depends not only upon the number of atoms present in the stellar atmosphere capable of absorbing the specified wave-length, but also upon the intrinsic probability that the atom will absorb light of that wave-length. Astrophysicists have been able to establish theoretical relations between the observed strengths of spectral lines and the abundances of the various atoms using the existing theoretical and experimental quantitative knowledge of the interaction between radiation and atoms. For this purpose a real stellar atmosphere is represented as a layer of gas at one temperature and one pressure. The relation that is derived is called a "curve of growth". From a detailed study of the intensities of the absorption lines in a stellar spectrum and from the theory of the curve of growth, one may deduce relative abundances of the elements and the average temperature and pressure in a stellar atmosphere.

In order to obtain more detailed information about the temperature and pressure gradients existing in real stellar atmospheres one usually proceeds by the method of "model atmospheres". In this method one uses physically exact, numerical representations of the temperature and pressure gradients in a stellar atmosphere to predict the strength of absorption lines. Model atmosphere methods, in principle, will yield more detailed information than will curve-of-growth methods, but the work is exceedingly laborious. Consequently, model atmospheres have been constructed for only a few of the simplest cases such as the sun and the B-type stars.

When the absorption lines in stellar spectra are studied in detail, it is found that the shapes of certain lines vary from star to star and that certain lines may be displaced from their expected positions. Normally forbidden lines may even occur. These details are all significant, and taken in conjunction with our knowledge of the interaction of radiation and atoms they enable us to deduce further information about the physical condi-

tions in stellar atmospheres. In particular the sensitivity of the hydrogen and helium lines to Stark effect (to the effect of electric fields) has proved of great value in estimating pressures and densities in stellar atmospheres.

So far in this discussion we have directed attention to some of the features of stellar spectra which will give us information about the temperature and pressure in stellar atmospheres and about the abundances of the elements. However, we may obtain further information. If a star is rotating rapidly, if its atmosphere is expanding or contracting steadily, if its atmosphere is more extended than usual, or if the gases in its atmosphere have large chaotic motions, the stellar spectrum will be deformed in a very characteristic way. For instance, the spectral lines all become very broad and shallow in a rapidly rotating star, while if the atmosphere is expanding the absorption lines will be displaced and they will become asymmetrical and shallow. In an unduly extended atmosphere the lines may become bell-shaped, and if there are large chaotic motions the spectral lines will become bell-shaped and perhaps even double. These and other departures from normality such as the occurrence of emission lines or the occurrence of sharp, deep absorption lines at a few selected wave-lengths when all the other absorption lines are broad and hazy are variations which are sometimes observed, and which give us much information about the stars.

The tracking down and interpretation of all possible clues to the physical conditions prevailing in the stars is a never-ending and always exciting puzzle. Even the continuous spectrum, which at first glance appears to be devoid of particular details which may be analysed, may be made to yield grist to the mill of astrophysics.

The slope of the continuous spectrum is related to the temperature in the stellar atmosphere. Thus if I_{red} is the intensity of the continuous spectrum at a red wave-length near 6500A. and I_{blue} is the intensity of the continuous spectrum at a blue wave-length near 4500A., the slope of the continuous spectrum may be measured by the quantity

$$G = -\frac{2.30 \log I_{red}/I_{blue}}{1/\lambda_{red} - 1/\lambda_{blue}}$$

which is called a *gradient*. If the star is cool, I_{red} will be greater than I_{blue}, and the gradient will be positive. If the star is very hot, I_{red} will be less than I_{blue} and the gradient will be negative. By means of astrophysical theory the size and sign of the quantity G may be related to the temperature and to the chemical composition of the stellar atmosphere. Thus the determination of G in several parts of the spectrum allows one to deduce important information.

The analysis of the continuous spectrum of stars in this way is more difficult than the analysis of the absorption-line spectrum, because it is very difficult to obtain good observations. In order to form the quantity *G*, we must know the *true* intensity in the continuous spectrum at each wave-length. Our "raw" observations, however, only give the intensity after the radiation has passed through interstellar space, the earth's atmosphere and our instruments. In order to obtain the *true* intensity we must correct our observations according to the manner in which the sensitivity of our observing equipment and the transmission of interstellar space and the earth's atmosphere vary with wave-length. Such corrections are difficult to evaluate and specially designed equipment and techniques must be used before meaningful results can be obtained. Nevertheless, the continuous spectrum of a star, in the cases in which it may be observed, is a fruitful source of information that complements the information that may be obtained from the line spectrum.

Dominion Astrophysical Observatory,
Royal Oak, B.C.

METEOR NEWS

By Peter M. Millman, *National Research Council, Ottawa*

Operation Perseid 1956

Under the above title the Regina Astronomical Society organized a very ambitious programme of observation of the Perseid meteor shower last year. Seven different groups of observers co-operated at stations located in various parts of Saskatchewan, and a total of 82 individuals took part. Over 2,800 meteors were visually recorded. Two meteors were photographed with direct cameras and one meteor spectrum was photographed—the second success in this difficult field by the Regina observers (see this Journal, vol. 50, p. 30, 1956). The organizations taking part in this operation were three sections of the Regina Astronomical Society at the Society Observatory, Base Line, and Regina Beach; the Moose Jaw Astronomical Society; the Indian Head Astronomical Society; the Saskatoon Astronomical Society; and the Kindersley Astronomical Society. A unique feature of the programme was the active co-operation of the Regina Amateur Radio Association under Mr. Keith Baker. By this means, various parties were kept in touch with each other during the progress of the shower.

The personnel taking part are listed below:

I. *Regina, Saskatchewan* (Lat. 50° 27′ N., Long. 104° 37′ W.)
Observers: G. Bitney, W. Clipsham, Miss J. Copithorne, G. S. Cumming, Mrs. J. Dunn, D. Fast, B. Haysom, Miss F. Hodges, G. Hodges, J. C. Hodges, Mrs. J. E. Hodges, J. V. Hodges, Mrs. L. Gilbert, A. Irwin, A. Kernechuk, I. Lipton, S. Lipton, T. R. MacFarlane, B. Maclean, E. P. Majden, Mrs. H. McLean, G. McNeely, K. Silzer, G. Sotiroff, C. Smith, Miss D. Smith, R. Sykes, G. R. Thompson, W. Vallis, M. Worel.
Radio: K. Baker, G. E. Ferguson, G. McDuff, L. O'Byrne, E. C. Odling.

II. *Regina Beach, Saskatchewan* (Lat. 50° 47′ N., Long. 104° 59′ W.)
Observers: Mrs. O. Beston, Miss A. Hallsworth, D. Hallsworth, Mrs. J. S. Hallsworth, J. S. Hallsworth, J. Kowalchuk.
Radio: A. Driver.

III. *Base Line, Saskatchewan* (Lat. 50° 12′ N., Long. 104° 38′ W.)
Observers: W. Clipsham, G. Hodges, E. P. Majden, G. McNeely.
Radio: K. Baker, A. O'Byrne, L. O'Byrne, Miss S. O'Byrne.

IV. *Indian Head, Saskatchewan* (Lat. 50° 32′ N., Long. 103° 40′ W.)
Observers: F. O. Burrill, C. A. Edwards, Mrs. C. A. Edwards, P. G. Flude, Mrs. P. G. Flude, H. Friesen, Mrs. H. Friesen, Galileo, G. Glenn, J. Hall, Mrs. J. Hall,

J. A. McKay, M. Robertson, J. Stephenson, L. G. Wilson.

V. *Kindersley, Saskatchewan* (Lat. 51° 28′ N., Long. 109° 09′ W.)
Observers: J. Knox, Jr., Mrs. J. Knox, Jr., Mrs. F. Nord, R. S. Reid, Mrs. Y. Reid.

VI. *Moose Jaw, Saskatchewan* (Lat. 50° 24′ N., Long. 105° 32′ W.)
Observers: F. Cushing, D. Keller, L. Larsen, Ralph McNabb, Rod McNabb, R. O'Brien, W. C. Treeman.

VII. *Saskatoon, Saskatchewan* (Lat. 52° 08′ N., Long. 106° 37′ W.)
Observers: T. Beck, R. Henderson, Miss G. Melville, D. Melville-Ness, Mrs. I. B. Melville-Ness, Miss M. Melville-Ness, T. Melville-Ness, T. Merchant, D. Thomas, Mrs. J. Thomas, O. Thomas.

The overall programme was organized under the guidance of Bernard Haysom, President, R.A.S., Edward P. Majden, Secretary, R.A.S. and John V. Hodges, Observatory Director. A summary of the visual meteors recorded is listed in Table I and the magnitude distributions are given

TABLE I

Station	Date (1956)	M.S.T.	Meteors P	Meteors N	No Observers (average)	Hourly Rates for Six Observers P	Hourly Rates for Six Observers N
I	Aug. 5/6	2100–2340	38	22	3	21	12
	6/7	2100–2300	18	23	5	13	13
	8/9	2100–2315	13	1	4	11	1
	10/11	2100–0100	114	33	6	33	12
	11/12	2100–0100	372	72	6	110	20
	12/13	2100–0100	177	30	6	50	9
II	Aug. 10/11	2100–0045	39	18	3	27	10
	11/12	2100–0110	328	56	3	115	17
	12/13	2100–0100	182	44	3	70	15
III	Aug. 9/10	2200–0100	45	6	4	42	6
	10/11	2200–0100	80	12	4	38	6
	11/12	2200–0100	186	17	4	77	9
	12/13	2200–0100	202	25	4	80	10
IV	Aug. 10/11	2210–2350	40	3		20	2
	11/12	2200–0020	148	6		66	4
	12/13	2100–2340	91	9		35	4
V	Aug. 12/13	2200–0005	123	33	4	70	20
VI	Aug. 11/12	2100–2305	99	25	5	55	15
VII	Aug. 10/11	2100–2150	8	4			
	11/12	2100–2120	3	4			
	12/13	2015–2300	43	48	8	20	20
	13/14	2100–2140	4	3			
			2,353	494			

in Table II. Excellent weather conditions were encountered for most of these observations. There was some cloud at Base Line on August 10/11 and Moose Jaw and Saskatoon were considerably hampered by bad weather, the latter station having to close up on three out of the four nights because of interference by clouds or aurora. Peak Perseid rates were observed on August 11/12, and considerably higher rates were recorded on August 12/13 than on August 10/11. Observers did not plot but watched the sky continuously, the magnitudes and numbers of the meteors being noted by recorders. In general, observer teams stayed on for an hour at a time and then were relieved by another team.

TABLE II

MAGNITUDE DISTRIBUTIONS

Station	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	Total	Mag.
P I		6	1 20	1 38	2 48	19 104	61 224	39 126	7 25	2 9	732	2.65
II	5	2 23	6 19	9 43	6 38	35 109	79 80	25 30	16 13	5 6	549	1.93
III			4	25	6 93	11 182	4 136	41	1 10		513	2.16
IV					11	9 65	1 108	1 70	11	3	279	3.00
V				7	8	23	9 21	14 12	29		123	3.10
VI	1	1	8	8	10	20	28	5	2		83	1.82
VII				1	6	2 14	3 13	1 11	1 6		58	2.85
Totals	6	2 30	7 51	10 122	14 214	76 517	157 610	80 295	25 96	7 18	2337	2.41
N I				6	5	3 30	19 53	12 35	5 11	1 1	181	3.02
II			2	2 4	5	4 12	25 28	14 11	5 5	1	118	2.75
III			1	2	5	1 22	22	6	1		60	2.41
IV					1	2	1 8	4	1	1	18	3.25
V						7	3 8	5 2	8		33	3.36
VI			1	1		6	11	2			21	2.48
VII				1	1	19	1 20	1 14	2		59	2.91
Totals			4	2 14	16	9 98	49 150	32 74	10 28	2 2	490	2.88

The cameras on the photographic programme were operated by J. V. Hodges, E. P. Majden, G. R. Thompson, R. G. Thompson, G. J. McNeely, Mrs. H. M. Maclean, and K. D. Baker. A total of 101 exposures was made with 8 cameras used at Stations I and III. Exposures with direct cameras totalled 22 hours, and with spectographs 4 hours.

The Perseid spectrum, photographed on Eastman Tri X film, is reproduced in figure 1. The meteor moved from left to right across the field, the blue end of the spectrum being down. The focus is good just at the edge of the film but becomes progressively worse along the meteor trail, possibly caused by buckling of the film. Lines of neutral sodium, magnesium, calcium and iron are prominent in this spectrum. The H and K lines of ionized calcium are weak at the beginning but strengthen steadily along the trail, contributing most of the light at the small burst near the

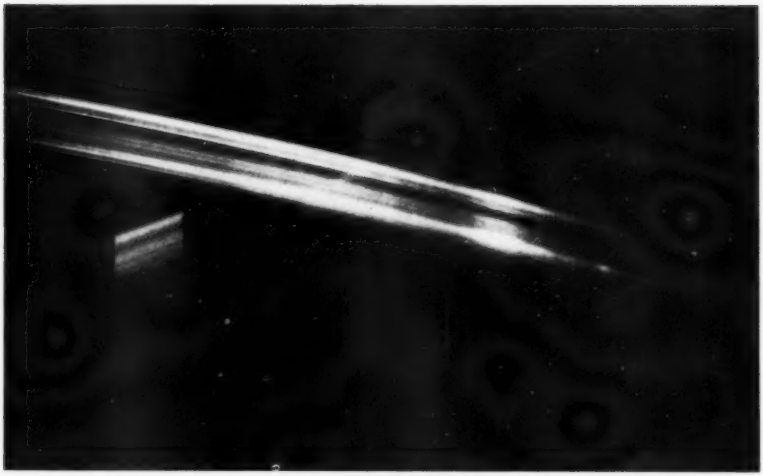

FIG. 1—Spectrum of a Perseid meteor photographed at Regina by the Regina Astronomical Society at $22^h\ 28^m\ 25^s$ MST on August 11, 1956. Meteor was of −2 with visual magnitude with a visual train lasting 11 seconds.

right-hand side of the figure. As is the case in so many spectra the red end of the spectrum and the D line of sodium are relatively strong at the beginning while the violet end of the spectrum is strong at the end of the trail.

Congratulations to the Regina group for an excellently organized and executed operation.

VARIABLE STAR NOTES

American Association of Variable Star Observers

By MARGARET W. MAYALL, *Director*

A CENTURY OF OBSERVATIONS OF U GEMINORUM

The variable star 074922 U Geminorum was discovered on the night of December 15, 1855 by John Russell Hind of Bishop's Observatory, Regents Park, London. He announced his discovery as a star of the 9th magnitude "shining with a very blue planetary light", in a part of the constellation Gemini where he had seen no star in the course of observing for 5 years. He suggested that it might be a new planet at its stationary point, or a new variable. It was soon proved to be the latter, for it was at least half a magnitude fainter on December 18, and 3 weeks later, when he next had a chance to look at it, it was fainter than 12th magnitude. The last of March 1856, Pogson observed it bright once again, and from that time on it has remained one of the most intriguing stars to observe.

U Geminorum has given its name to the class of variation which includes the more famous and better observed SS Cygni. The U Geminorum stars are variables which remain fairly constant at or near minimum light most of the time, and have sudden bursts of brightness at intervals of 10 to more than 500 days. The variables with the shorter intervals between outbursts have smaller ranges of brightness. Not much is known about their spectra, for they are mostly quite faint, but they are all very blue stars and are probably subdwarfs.

The variable U Geminorum has a mean interval between outbursts of 102 days, about double that of SS Cygni, and has a range of brightness from 14.2 to 8.8, nearly 5½ magnitudes, in contrast to the 4-magnitude range of SS Cygni.

The following table lists observed maxima of U Gem since its discovery in 1855. For each observed maximum is given the number of the Epoch; the type of maximum (w = wide, n = narrow); the Julian date of magnitude 11.0 when the variable is increasing; the difference, or interval elapsed since the same point on the last observed maximum; the Julian date of magnitude 11.0 on the decreasing branch of the curve; and lastly, the interval from the same point at the previous maximum.

U Geminorum differs from SS Cygni in that the maxima are alternately wide (10 to 20 days) and narrow (3 to 8 days). A few anomalous maxima occur and temporarily break the rhythm of alternation, but in general, the odd epochs are narrow and the even epochs are wide.

For the first 80 years the material of the table is taken from an unpublished compilation of all available material by Leon Campbell. The data for the later years, from 1938 on, depend almost entirely on A.A.V.S.O. observations.

The mean interval between maxima for the 363 epochs listed in the table is 101.8 days. There is a slight indication of an increase in the length of the interval. For the first 50 years of observation, its mean is 96.5 days, and for the second 50 years, it is 107.6 days. The intervals vary in length from 57 days to 201 days.

Observed Maxima of 074922 U Geminorum

E	Type	11.0 I	Diff.	11.0 D.	Diff.	E	Type	11.0 I	Diff.	11.0 D.	Diff.
1	—	2398930±	—	—	—	140	w	2412442±	322	2412456	101
2	—	—	—	2399038	—	142	w	2578	136	2589	133
6	w	9410±	480	9420	382	144	w	2803	225	2817	228
8	w	9618	208	9632	212	145	—	—	—	2910	93
13	n	9998	380	2400003	371	147	n	3168	365	3173	263
14	w	2400091±	93	0102	99	148	w	3257	89	3270	97
17	—	—	—	0368	266	149	—	3356±	99	—	—
18	w	0520	429	0532	164	150	w	3492	136	3503	233
22	w	0897	377	0911	379	152	w	3634	142	3646±	143
24	w	1139	242	1152	241	155	n	3894	260	3898	252
26	—	—	—	1401	249	156	w	3986	92	3996	98
27	n	—	—	1501	100	157	—	4080±	94	—	—
28	w	1598	459	1610	109	158	—	—	—	4157	161
30	—	—	—	1744	134	159	n	4252	172	4258	101
31	n	1866±	268	1870	126	160	w	4326	74	4337	79
33	n	—	—	2142	272	161	—	—	—	4421	84
34	w	2234±	368	2248	106	163	—	4610±	284	—	—
35	n	2346	112	2351	103	164	—	—	—	4718	297
38	w	2619	273	2632	281	165	n	4779	169	4783	65
39	n	2709	90	2713	81	166	—	—	—	4927	144
42	w	3037	328	3046	333	167	n	5020	241	5023	96
44	w	3307	270	3320	274	168	w	5108	88	5120	97
46	w	3452	145	3464	144	170	—	5296±	188	—	—
48	w	3594	142	3606	142	171	n	5370	74	5374	254
50	w	3742	148	3754	148	172	w	5462	92	5475	101
53	n	—	—	3976±	222	174	w	—	—	5735	260
54	w	4076	334	4089	113	175	n	5853	391	5858	123
55	n	4152	76	4158	69	178	w	5932	79	5943	85
56	w	4300±	148	4314±	156	181	n	6384	452	6388	445
57	n	4425	125	4433	119	182	w	6456	72	6466	78
58	w	4557	132	4572	139	183	n	6548	92	6552	86
62	w	4845	288	4860	288	186	w	6810±	262	6821	269
64	w	5070	225	5085	225	187	—	—	—	6890	69
66	w	5215±	145	5229	144	188	w	6955	145	6966	76
68	w	—	—	5454	225	189	—	7092±	137	—	—
69	—	—	—	5562	108	190	w	7154	62	7166	200
72	w	5902±	687	5914	352	191	n	7256	102	7259	93
80	w	6672	770	6684	770	194	w	7532	276	7542	283
83	—	—	—	6978	294	195	n	7599	67	7603	61
84	w	7092±	420	7106	128	196	w	7685	86	7696	93
86	—	—	—	7370	264	198	w	7841	156	7852	156
89	—	—	—	7651	281	200	n	7980	139	7985	133
90	w	7739	647	7754	103	202	n	8252	272	8260	275
91	n	7854±	115	—	—	203	w	8373	121	8386	126
92	w	7940±	86	7952	198	204	—	8450±	77	—	—
93	—	—	—	8073	121	205	w	8556	106	8566	180
94	w	8172	232	8184	111	206	w	8698	142	8708	142
98	w	8498	326	8511	327	207	n	8794	96	8799	91
99	—	8592±	94	—	—	209	—	8944±	150	—[4]	—
101	n	—	—	8766	255	210	w	9036	92	9046	247
102	w	8835	243	8849	83	211	n	9162	126	9168	122
104	w	9104±	269	9118	269	214	w	9471	309	9483	315
105	n	9201	97	9206	88	216	n	9706	235	9712	229
106	w	9304±	103	9318	112	217	—	9781	75	9790	78
108	w	9470±	166	9481	163	221	n	2420008	227	2420011	221
109	—	—	—	9548	67	222	w	0098	90	0109	98
110	w	9636	166	9646	98	223	n	0182	84	0186	77
112	—	—	—	9812	166	224	w	0264	82	0276	90
113	—	—	—	9888	76	226	n	0478	214	0483	207
114	w	9970	334	9982	94	227	n	0562	84	0567	84
116	w	2410236	266	2410249	267	228	—	0643	81	—	—
117	n	0325	89	0330	81	230	w	0930	287	0941	374
119	—	—	—	0540	210	233	n	1241	311	1245	304
120	w	0635±	310	0644	104	234	w	1343	102	1354	109
121	n	0745	110	0751	107	236	w	1554	211	1564	210
123	n	0941	196	0946	195	237	n	1641	87	1645	81
124	w	1024	83	1036	90	238	w	1734	93	1745	100
125	—	—	—	1149	113	240	w	1953	219	1965	220
126	—	—	—	1267	118	241	n	2052	99	2056	91
128	w	1380±	356	1393	126	243	n	2209	157	2214	158
129	n	—	—	1453	60	244	w	2284	75	2295	81
132	w	1740	360	1753	300	245	n	2360	76	2365	70
133	—	—	—	1873	120	246	w	2446	86	2456	191
135	n	2038	298	2042	169	248	w	2601	155	2610	154
136	w	2120±	82	2131	89	249	n	2681	80	2685	75
139	—	—	—	2355	224	250	w	2766	85	2777	92

E	Type	11.0 I	Diff.	11.0 D.	Diff.	E	Type	11.0 I	Diff.	11.0 D.	Diff.
252	w	2422986	220	2422998	221	305	w	2429308	134	2429318	131
253	n	3070	84	3074	76	306	—	9492±	184	—	—
254	w	3169	99	3180	106	308	w	9676	184	9687	369
256	w	3342	173	3353	173	310	—	—	—	9876	189
257	n	3464	122	3471	118	311	n	9996±	320	—	—
260	w	3821	357	3834	363	313	n	2430268±	272	—	—
262	w	4150	329	4165	131	314	w	0418	150	2430430	554
263	n	4262	112	4267	102	316	w	0614±	196	0626	196
264	n	4422	160	4425	158	318	w	0838	224	0850	224
265	n	4491	69	4496	71	319	n	0972	134	0978	128
266	w	4600	109	4612	116	321	w	1224	252	1240	262
268	w	4761	161	4772	160	323	—	—	—	1378	138
269	n	4902	141	4907	135	324	w	1480	256	1494	116
271	n	5189	287	—	—	325	n	1598	118	1602	108
272	w	5280	91	5291	384	328	w	1808	210	1824	222
273	n	5368	88	5373	82	329	n	1938	130	1945	121
274	w	5504	136	5518	145	330	w	2084	146	2099	154
276	w	5761	257	5777	259	331	n	2181	97	2185	86
278	w	5995	234	6006	229	332	w	2329	148	2341	156
280	w	6434	439	6449	443	333	w	2475	146	2485	144
281	n	6635	201	6642	193	334	w	2610	135	2622	137
282	w	6792	157	6804	162	336	w	2847	237	2858	236
284	w	7071	279	7082	278	338	w	3044	197	3057	199
285	n	7144	73	7149	67	340	w	3236	192	3245	188
288	w	7470	326	7486	337	342	w	3421	185	3434	189
291	n	7800	330	7805	319	343	—	3572	151	—	—
292	w	7877	77	7889	84	344	n	3693	121	3698	264
293	n	7955	78	—	—	346	w	3961	268	3971	273
294	w	8098	143	8108	219	347	n	4088	127	4094	123
295	n	8189	91	8193	85	350	w	4498	410	4511	417
296	w	8301	112	8314	121	352	w	4804	306	4814	303
298	w	8514	213	8527	213	355	n	5080?	276	—	—
301	n	8833	319	8838	311	356	n	5137	57	5143	329
302	w	8928	95	8940	102	360	w	5462	325	5470	327
303	n	9034	106	9037	97	361	n	5562	100	5566	96
304	w	9174	140	9187	150	363	n	5774	212	5779	213

Observations received during November and December 1956: In November 51 observers sent 5,097 observations, and in December 47 sent 4,106, a total of 9,203 for the two months.

Observer	November Var.	November Ests.	December Var.	December Ests.	Observer	November Var.	November Ests.	December Var.	December Ests.
Adams, R. M.	86	210	83	205	Kimball, M.	..	..	9	9
Ancarani, M.	16	29	..	..	de Kock, R. P.	141	540	140	736
Anderson, C. E.	63	101	65	105	Kofoed, R.	..	..	6	8
Aronowitz, C.	5	5	..	..	Lacchini, G. B.	64	221	51	67
Barnhill, M. V.	..	..	5	7	Mayall, M. W.	5	10	1	1
Beidler, H. B.	15	15	..	..	McPherson, C. A.	32	32	11	11
Berg, R.	2	2	..	..	Miller, R. W.	15	15	..	..
Breckinridge, J.	10	13	1	1	Montague, A. C.	43	59	28	29
Brinley, F. J.	..	..	2	2	Morgan, F. P.	18	39	22	44
Brown, R. A.	2	3	..	..	Oravec, E. G.	239	571	222	586
Buckstaff, R. N.	10	16	6	10	Parker, P. O.	73	95	74	102
Carlisle, J. H.	..	..	1	4	Pearcy, R. E.	7	7	2	2
Carpenter, C. B.	28	28	45	49	Peltier, L. C.	26	74	24	46
Churns, M. T.	..	..	5	9	Pilcher, F.	28	33	15	17
Cragg, T. A.	389	427	281	292	Price, F.	12	18	11	18
*Darsenius, G. O.	16	122	17	60	Renner, C. J.	..	..	216	307
Diedrich, DeL.	..	..	1	1	Rizzo, P. V.	23	33	24	31
Diedrich, G.	6	7	1	1	Robinson, L. J.	6	8	10	13
Erpenstein, O. M.	13	15	15	33	Rosebrugh, D. W.	18	150	17	135
Fernald, C. F.	219	651	277	408	Royer, R.	5	9	3	3
Ford, C. B.	252	312	197	215	Scholly, P. R.	4	9	..	..
Fowler, C. E.	3	10	4	9	Segers, C. L.	..	..	13	24
Gemberling, R. H.	40	46	6	18	Sharpless, A. P.	10	10	..	..
Glenn, W. H.	16	33	..	..	Skaritka, P.	114	195	..	..
Goldenblatt, P. P.	36	36	..	..	Socha, E. M.	2	6	2	3
Goodsell, J. G.	2	2	2	2	Solomon, L.	62	75	10	11
Gordon, L.	6	6	..	..	Taboada, D.	219	277	158	270
Hartmann, F.	153	175	170	178	Tsai, C. H.	..	..	9	9
Hutchings, N.	5	5	..	..	**Venter, S. C.	98	314	..	..
Isenberg, H. D.	3	6	1	1	Walko, K.	7	7	4	4
Kelly, F. J.	10	15	..	..	Wolfe, J. C.	..	..	5	10

*plus EV Lac 43^m; EQ Peg 20^m **plus 2^h 40^m AE Aqr

A.A.V.S.O. Nova Search Report (from George Diedrich, Chairman): The following 11 observers checked their nova search areas for the number of area-nights as indicated after their name. The first number after the name is the October and the second is the November 1956 total: JAMES BRECKINRIDGE: 5, 3; DELORNE DIEDRICH: 6, 4; GEORGE DIEDRICH: 10, 4; PAUL DIEDRICH: 10, 0; R. H. GEMBERLING: 8, 8; ANDREW KEEFER, JR.: 6, 0; EARL MILTON: 18, 0; BEAUFORT RAGLAND: 9, 3; LOUIS RICK: 27, 3; WILLIAM H. SULLIVAN: 28, 0; SAMUEL TERRY: 9, 8.

A.A.V.S.O. Headquarters,
4 Brattle Street,
Cambridge 38, Massachusetts,
January 1957.

NOTES FROM OBSERVATORIES

Dominion Astrophysical Observatory, Victoria, B.C.

Staff. Mr. J. D. Francis was appointed to the staff as Astronomical Assistant and commenced his duties on August 20. Mrs. D. M. Sewell, who has been secretary of the Observatory for eight years, resigned on November 1. Miss T. C. Thompson was appointed in her place and commenced her duties on November 1. Dr. Andrew McKellar and Dr. R. M. Petrie attended the Berkeley meeting of the American Astronomical Society in August and Dr. G. J. Odgers attended the Christmas meeting of the American Astronomical Society in New York. Dr. Andrew McKellar was re-elected President of the Astronomical Society of the Pacific for a second term at the Annual Meeting of the Board of Directors held in January.

Dr. R. S. Kushwaha took up residence on September 1 as a National Research Council Post-doctoral Fellow. Dr. Kushwaha will be working chiefly on the problem of β Cephei variation.

Visitors. Dr. W. W. Morgan, of the Yerkes Observatory, spent several weeks at Victoria during November and December, 1956, as a temporary member of the staff. During his stay Dr. Morgan discussed numerous spectroscopic problems and gave a series of seminars on the subject of stellar associations and stellar evolution. He also discussed the problem of the stellar distance scale with special reference to the spectroscopic absolute magnitudes of B-type stars. During his visit Dr. Morgan addressed the Victoria Centre of the Royal Astronomical Society of Canada at its annual dinner. Other visitors to Victoria include Dr. S. C. B. Gascoigne, of Canberra, Australia, and Dr. Rupert Wildt, of Yale University, New Haven, Connecticut.

During the fall and winter extensive coverage was attempted on the famous eclipsing stars VV Cephei and ϵ Aurigae. A good series of high-dispersion spectra was obtained on each one of these objects and the observations are being continued as weather permits. Good spectrographic coverage was obtained also on the short-period β Cephei stars, 12 Lacertae, β Cephei and ν Eridani. The observtions on 12 Lacertae were part of an international co-operative scheme designed to cover this interesting star both spectrographically and photometrically during a continuous observing period of some two weeks.

Specifications for a second telescope have been prepared and it is hoped that it will soon be possible to receive tenders and that a contract may be awarded for its construction. The proposed new instrument is to be erected at the Dominion Astrophysical Observatory. It will be a 48-inch reflector and its chief purposes will be for spectrographic work at a Coudé focus and photoelectric photometry at a Cassegrainian focus. Some novel features of the design will make this telescope adaptable also for various experimental purposes.

R. M. PETRIE

REVIEW OF PUBLICATIONS

Gaseous Nebulae by L. H. Aller. Pages 322, 6 × 9½ in. London, Chapman and Hall Limited, 1956. Price 63*s*.

It has been remarked that while the study of the stars is among the oldest intellectual activities of man, the study of the material between the stars is one of the most recent. Knowledge of the interstellar gas and dust has increased enormously within the last decade but while excellent descriptive accounts are available there is at present no text-book or monograph dealing with the physical processes occurring in the diffuse gas which makes up such an important constituent of our galaxy.

This book partially fills this need. It deals with that portion of diffuse gas in space, which being in close proximity to hot stars is caused to shine by their radiation. The discussion of planetary nebulae occupies a large fraction of the book.

Chapters IV and V (on the Physical Processes in Gaseous Nebulae and the Forbidden Lines) contain the theoretical discussion and form the core of the book. In them, students at the graduate level will find a concise account of the interaction of stellar radiation with nebular material and the physical processes which account for the emitted spectrum of the irradiated gas. Here, and throughout the book, the serious reader will be gratified to find an extensive bibliography referring him to original papers in the literature.

Chapters on observational techniques, description of nebulae, their structure and motion and the stars that illuminate them will be intelligible to a wider audience and contain much interesting material. The

student and research worker will want to read these comprehensive accounts though they will doubtless reflect that present activity in astrophysical research will rapidly render them obsolescent. The last chapter is concerned with the diffuse gaseous nebulae and deals rather sketchily with selected topics from this large field.

There is at present no other book in English that covers this material and for students at the graduate level it will provide a thorough and welcome guide to the physics of the planetary nebulae and related topics.

The book contains beautiful and instructive illustrations and is pleasingly printed and bound; it appears to contain few typographical errors.

LEONARD SEARLE

The Life of Arthur Stanley Eddington by A. Vibert Douglas. Pages xi plus 207, 15 plates; 6¼ × 9¾ inches. Edinburgh, Thomas Nelson and Sons Ltd., 1956. Price 25*s*.

It is now eleven years since Eddington died. During this time it has become apparent that Eddington's work in astrophysics constituted not a mere series of contributions to a newly developing science; it was more in the nature of the foundation of a new understanding of the stars in the light of modern physics. It required more than knowledge and skill; it required also a rare perception to see the connection between the physics of the atoms as revealed in laboratory experiments and the physics of the stars as revealed by the few measurable quantities made available by observation; it required also a rare intuition to anticipate atomic research and confidently to predict principles of atomic energy which we have seen verified since Eddington's death.

Only occasionally in the history of scientific thought has one man been able to give such leadership. When it has happened unmistakably, then the story of his life and work assumes a great importance not only to workers in his field and in allied fields, but to all who hope to have some understanding of modern science. For this reason a biography of Eddington and a survey of his work is overdue.

Dr. Douglas, now Dean of Women at Queens University, is singularly qualified to write Eddington's biography. She was his student in Cambridge in the early 1920's and remained his friend and frequent correspondent until the end of his life. Eddington's sister, Miss Winnifred Eddington, asked Dr. Douglas to write his biography and put at her disposal a great wealth of notes, correspondence and clippings relating to her famous brother. In addition, Dr. Douglas had access to material

which had been assembled by Eddington's life-long friend, Mr. C. J. A. Trimble.

A person who lacked an understanding of Eddington's work, no matter how well he knew him, would surely have written a dull biography, for, to tell the truth, his life was uneventful enough. He was so quiet and shy that he must have appeared dull to many who met him on other than a scientific level. It was in the fertility of his remarkable mind that the excitement took place, and it was his amazing scientific perception that made him one of the most fascinating personalities of his day. Dr. Douglas has emphasized these contrasts by interspersing chapters describing the simplicity of his private life with chapters describing the vigour of his scientific life.

Frankly, the reader of Dr. Douglas' book must be prepared to be bored if he has no great interest in astronomy or physics or philosophy. But if he has any such interest and especially if he is one of the devotees of Eddington's own popular works, he will find this book hard to put down. He will not understand Eddington's work completely by any means, for there are parts of it which neither Dr. Douglas nor anyone else understands. But he will understand enough to realize that Eddington was a phenomenon among scientists.

Dr. Douglas has arranged her material skilfully and has written beautifully. She has made copious use of quotations from Eddington's own work and has, with fairness, quoted his critics. She has taken the reader cycling and glissading with Eddington and has also tried to lead him through Eddington's obscure "Fundamental theory". She has described the painful experiences of a conscientious objector during World War I and the brilliant campaign that he waged against his scientific antagonist, Jeans. From her chapters emerge a vivid picture of Eddington, the man, the scientist and the mystic.

J. F. H.

NOTES AND QUERIES

Artificial Satellites

The launching of man-made satellites is one of the most spectacular projects being planned for the International Geophysical Year, July 1957–December 1958. The satellites, some 20 to 30 inches in diameter and weighing approximately 20 pounds, will be filled with delicate instruments which will give us information which will be valuable in such fields as geodesy, atmospheric physics, ionospheric physics, auroral physics and solar radiation. During the eighteen months about a dozen satellites may be launched. Each satellite may stay in flight anywhere from a few days to a few months.

The orbit of a satellite will be an ellipse, which is expected to bring the satellite to within about 200 miles of the earth's surface at the closest point and possibly as far as 1,000 or 1,500 miles at the farthest point. The plane of the orbit will be inclined about 40 degrees to the equator. The motion of the satellite will be affected by both the gravitational pull of the earth and the density of the upper atmosphere. The slow changes in the orbit will provide accurate information concerning the density of the air and, from the precession of the orbit, the amount of flattening of the earth. Even the distribution of the mass inside the earth and the unevenness of the mass of the earth's crust can be deduced from observations of changes in the orbit of the satellite. By observing the satellite from a number of stations on the earth, the positions of locations on different continents can be determined with an accuracy much higher than that of present measures.

The problem then, once the satellite is in flight, is to follow its motion accurately. It will be observable only at twilight. When closest to the earth its magnitude is expected to be 5.7, near the limit of naked-eye visibility, and it will be moving at the apparent rate of 1½ degrees a second (three times the moon's diameter in a second). When farthest away its magnitude may be 10, and it will be moving at a tenth of the above speed. These magnitudes assume the satellite to be at the zenith; for a zenith distance of 50° it would be one magnitude fainter. It is evident that it requires ingenuity to find and photograph such a fast-moving, faint, object. The problem of tracking the satellite will be divided into three phases: stations will pick up radio signals from a

small battery-powered transmitter in the satellite; observing teams will use low-power wide-field telescopes for visual tracking; a dozen stations around the world will be equipped with specially-designed Baker-Nunn cameras for precision photographic tracking.

The Baker-Nunn camera (see *Sky and Telescope*, vol. 16, p. 108, 1957) is a modification of the Schmidt design, and has a focal ratio of f/1.0. The mirror is spherical with a diameter of 31 inches. The focal surface has a radius of curvature of 20 inches. The three components of the correcting plate are unusual kinds of glass which reduce the chromatic aberration to zero at three specific wave-lengths. The field of view is 5 by 30 degrees, and is photographed on a strip of film 55 mm. wide and about a foot long.

The camera is designed to follow the satellite in its motion to an accuracy of one per cent. This means that the star images will trail, and only stars brighter than magnitude 5.8 will be recorded when the satellite is at perigee. Two or three stars of this brightness would appear on each film, but may be some inches from the image of the satellite. Errors in measuring long distances could occur because of stretching and distortion of the film. To avoid this trouble, the camera will alternately move at the rate of the satellite and at the sidereal rate; this will "bring up" the images of the faint stars close to the image of the satellite. Thus measurements of great distances on the film will be avoided. The camera will operate in cycles, the time of each cycle being accurately and automatically recorded. It is hoped that the measured values will lead to positions of the satellite to an accuracy of two seconds of arc.

The sites of the stations for these cameras include central Florida; Hawaii; Tokyo, Japan; central Australia; Curacao, Netherlands West Indies; Bloemfontein, South Africa; and possibly Cadiz, Spain; Teheran, Iran; Dehra Dun, India; Cordoba, Argentina; and Arequipa, Peru. Each station may be able to photograph the satellite once a week. In order for observations to be made the satellite must come near the station at twilight. A few hours before the expected transit, details about the position and brightness of the satellite will be sent to the station by radio from the computing centre at Cambridge, Massachusetts. Once the camera is set in position and started, the rest of the operation is automatic. The photographs, which may number between 10 and 100 during each transit, will be developed at once, rough measures of the position of the satellite made and sent by radio to Cambridge to be used in improving the predicted position of the satellite for the next station. Within a few minutes high-speed computing machines will give the improved position which is necessary for the next station to find and follow the satellite.

The film will then be shipped to the computing centre for accurate measuring. The final analysis of all the data to determine the geodetic and geophysical results will be done after observations of all the I.G.Y. satellites have been made. The photographic tracking of the satellite is a challenging programme, and is under the supervision of Dr. Fred L. Whipple and Dr. J. Allen Hynek.

R. J. N.

Rumford Premium Awarded to S. Chandrasekhar

Subrahmanyan Chandrasekhar, Distinguished Professor of Theoretical Astrophysics at the Yerkes Observatory of the University of Chicago, at Williams Bay, Wisconsin, received the 1957 biennial Rumford Premium of the American Academy of Arts and Sciences on March 13, 1957.

The award was for work on radiative transfer of energy in the interior of stars. The citation by the Rumford Committee of the Academy reads: "To Subrahmanyan Chandrasekhar for extending to the cosmic realm the stochastic laws which, on the atomic scale, govern the phenomena of heat; and for his monumental work, 'On the Radiative Equilibrium of a Stellar Atmosphere', in which heat is transported as light, and light supports matter, and matter is ultimately the source of heat itself."

The historic Rumford Premium was established by a gift of Benjamin Thompson, Count Rumford, to the Academy in 1796 for the purpose of honouring the author of outstanding discoveries in light and heat. A total of 49 awards of the Rumford Premium have been made.

Ralph W. Burhoe

Annual Meeting of the R.A.S.C. in the June Journal

Since 1916 the report of the annual meeting of the Royal Astronomical Society of Canada has appeared in the March or March–April issue of the Journal. With the growth of the Society the work of carefully auditing the books has increased tremendously. In order to allow ample time for the preparation of the reports the date of the Annual Meeting was scheduled in February instead of in January as in previous years. The president's address and the reports presented at the Annual Meeting will appear in the June number of the Journal.

The Editor

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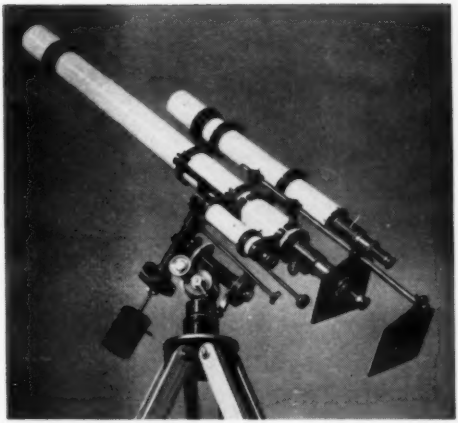

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